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# Wide-range plutonium Isotopic Analysis with CdTe detector

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## Summary

### 1. Introduction

Nondestructive analysis (NDA) techniques applied to bulk nuclear materials (NM) are important for nuclear safeguards and material control because of timeliness, cost-effectiveness and containment integrity. The common NDA techniques, calorimetry and neutron coincidence counting, require knowledge of the isotopic composition of the material quantitative interpretation of these measurements. Gamma-ray spectroscopy with high-resolution detectors is a well-developed NDA technique for isotopics.

The use of intrinsic germanium detectors cooled to cryogenic temperatures for isotopic measurements is sometimes difficult or even impossible because of severe access limitations with the sensitive, heavy detectors. Highly portable isotopics measurements are needed for *in-situ* verification of bulk NM quantities or, in many cases, for measurements of holdup quantities.

This paper summarizes the gamma-ray measurements with a new, portable CdTe detector. It also presents the detailed results of the wide-range isotopic analysis of plutonium with FRAM v4 [1,2], the first results of this kind for a non-cryogenic detector.

### 2. Experimental Overview and Detector Performance

We tested a new, large-area (10 mm x 9 mm x 1.5 mm-thick) Peltier-cooled CdTe detector. The cooler is regulated to ensure constant detector temperature independent of the ambient temperature. The detector comes with a portable unit that supplies the power to the detector (both the high voltage and power for the Peltier cooler). This unit also corrects for charge loss in the CdTe crystal that arises from known transport limitations in this material. The charge-loss correction improves spectral resolution without throwing away counts. The analog output of the charge-loss correction circuit connects to the linear amplifier of any multi-channel analyzer (MCA) system, and the operating system is any software that controls the MCA.

The resolution of the CdTe detector is about 3 times worse than that of a planar HPGe detector and about 3 and 10 times better than that of CdZnTe and NaI detectors, respectively. The CdTe efficiency is low because of its small size. However, its excellent resolution (compared with other portable detectors) can offset the lower efficiency in some applications.

### 3. Plutonium Isotopic Results with the CdTe Detector

We measured 13 small reference samples of plutonium oxide of well-known isotopic composition covering a wide range of burnup, from a low $^{240}$Pu fraction of 3.6% to a high of 26%. The masses of these samples range from 0.4 to 20 g.

Three different MCA systems (DSPEC Plus, Inspector 2000, and MCA-166) were used with the CdTe detector to collect data from these samples. The acquisition time was 1 hour for each spectrum. A total of 23 spectra were collected.

There are several differences between a CdTe spectrum and a germanium spectrum that must be addressed to successfully do isotopic work with the CdTe detector. Even though the resolution of the CdTe detector is excellent compared to that of other portable detector systems, it is still about 3 times worse than that of a germanium detector. Some of the peaks that are clearly separated in a germanium spectrum may not be completely resolved in a CdTe spectrum. This creates a new challenge for extracting information from such peaks. Also, the broad peaks greatly reduce the regions available for determining the continuum background that must be subtracted from the peaks.

Another challenge is the large low-energy tails on the gamma-ray peaks, which exceed those from spectra taken with germanium detectors by about an order of magnitude. These large tails need to be determined accurately for successful analysis.

Yet another analysis problem with the CdTe spectra is that the cadmium and tellurium escape peaks are large because the detector is very thin. The escape peaks introduce additional interference to all the peaks in the spectrum and need to be explicitly accounted for in the analysis.

The CdTe spectra obtained with the 13 reference samples were analyzed with FRAM v4. The results were excellent for this portable detector. The $^{240}$Pu average bias was about 3% with a standard deviation of 8%, and the average bias for the specific power was –0.4% with the standard deviation of 3%.

## 4. Discussion

As the technology of the CdTe detector continues to improve, and as larger and thicker CdTe detectors becomes available, this type of CdTe detectors may replace CdZnTe and NaI detectors in many applications requiring portable systems. Because the performance of this CdTe detector is so much improved over that of CdZnTe, the CdTe crystals required to replace CdZnTe can be smaller than those of CdZnTe. Some portable needs for *in-situ* plutonium gamma ray isotopics can be addressed using the present CdTe detectors, whose crystals are sufficiently large to achieve the *in-situ* isotopic results that are required for verification and holdup measurements.

## REFERENCES


1. T.E. Sampson and T.A. Kelley, “PC/FRAM: A Code for the Nondestructive Measurement of the Isotopic Composition of Actinides for Safeguards Applications,” *Appl. Radiat. Isot.* **48**, 1543 (1997).
2. T.E. Sampson, T.A. Kelley, and D.T. Vo, “Improvements in the PC/FRAM Isotopic Analysis Software,” Proceedings of the Sixth International Conference, Facility Operations-Safeguards Interface, Jackson Hole, Wyoming, September 20-24, 1999, 206-211.